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# Assessment and Implementation Techniques for Road-related Sediment Inventories

# Assessment and Implementation Techniques for Road-related Sediment Source Inventories and Storm-proofing

**Upland Watershed Sediment Source Assessments**

There is recent, growing recognition that effective fisheries protection and restoration, and the long term recovery of gravel-bedded anadromous fish streams, is directly dependent on the recovery and healing of eroding hillslopes and tributary streams in upland areas of a watershed (Weaver and Hagans, 1990; PRC, 1992; Harr and Nichols, 1993). Similarly, cost-effective erosion prevention projects conducted on logged and roaded hillslope areas throughout a watershed can protect healthy stream channels from future impacts (Weaver and others, 1987b; Weaver and Sonnevil, 1984; Harr and Nichols, 1993).

A watershed sediment source assessment and erosion prevention planning project entails the delineation of treatable, persistent or potentially episodic sources of eroded sediment which contribute or threaten to deliver significant quantities of sediment to streams. The assessment entails delineating past and future sediment sources in the watershed, and describing how sediment is eroded, and how it moves into the stream channel system. It is important to learn how much sediment is coming from each of the major erosion processes (e.g., landslides along roads, and stream crossing washouts), and how much of that is amenable to control or prevention.

The inventory process is similar to a “modified” sediment budget analysis (Dietrich and Dunne, 1978) where sediment delivered to the streams in a watershed is identified and quantified. However, the sediment source assessment targets future sediment sources (rather than what has happened in the past) and its primary focus is to identify and prioritize all potential sources of erosion and sediment yield that are amenable to treatment. Sources of past erosion and sedimentation are identified during the assessment process, but they are of interest mostly in what they tell us about similar areas that have not yet failed but may yield sediment in the future.

There are three main objectives of a sub-watershed sediment assessment project. The objectives, and the tasks carried out to complete them, include:

1. Conducting a physical inventory of existing and potential sediment sources which are likely to deliver sediment to the sub-watershed and its tributary streams if they are not treated;

2. Developing a practical, fact-based, prioritized listing of cost-effective erosion control and erosion prevention projects. These projects are recommended to provide for long-term protection of fish- and non-fish bearing stream channels in the sub-watershed, its tributaries and in downstream areas, and;

3. Analyzing the erosional effects of past and current land management and land use practices in the watershed, with the goal of developing possible changes in land management practices, techniques or intensities that could reduce the future delivery of sediment to streams.

In most upland forest watershed inventories and assessments, logging roads are initially singled out in the analysis both because the road network provides ready access for heavy equipment to reach potential work sites, and because roads have been identified throughout the region as serious, treatable sediment sources themselves. Studies conducted in the coastal and Cascade mountains of northern California, Oregon and Washington have found roads to be a primary, land use-related contributor to on-site erosion and downstream sediment yield that impact fish bearing streams (Swanson and Dyrness, 1975; Swanston and Swanson, 1976; Dyrness, 1967; Reid, 1981; Weaver and others, 1981a; Frissell and Liss, 1986; Fiksdal, 1974; Farrington and Savina, 1977; LaHusen, 1984; Hagans and others, 1986; Weaver and others, 1987b; Pacific Watershed Associates, 1994a,b). As discussed previously, these impacts become most apparent in response to large storms and floods which trigger watershed-wide erosion and geomorphic change.

Stream crossings, log landings, oversteepened sidecast and road fills built in "suspect" geomorphic locations are prime areas where cost-effective erosion prevention projects can keep large quantities of sediment from entering streams and being transported to important spawning and rearing areas (Weaver and others, 1987b; Harr and Nichols, 1993).

**Conducting an Upland Watershed Assessment**

It is necessary to follow an organized, systematic series of steps in assessing watershed sediment conditions. Only then can you ensure that erosion control and erosion prevention work will treat those sources of future erosion and sediment yield that could be effectively controlled for the lowest expenditure. It is not cost-effective to take the shot-gun approach, where problem areas are randomly identified and treated without regard to their importance in overall watershed health or to our ability to cost-effectively control or prevent stream sedimentation.

1) <u>Air photo analysis:</u> As the first step, an air photo analysis of the watershed is conducted to help reveal the location of sensitive roads and other high priority areas for further field mapping, analysis and potential treatment. It is important to identify <u>all</u> the roads that have ever been constructed in the watershed, whether they are currently maintained and driveable, or are now abandoned and overgrown with vegetation. When possible, historic aerial photographic coverage from a number of years (perhaps one or two flights per decade) should be selected to “bracket” major storms in the watershed. This will allow the identification of roads which have been “storm-tested,” and closer analysis will reveal at least some of the most obvious erosional consequences of storm (stream crossings washouts, landslides, debris torrents, etc.). A preliminary transportation plan is developed for the watershed at this time, outlining the best long term permanent and seasonal road network needed to manage natural resources.

2) <u>Field assessment and prioritization:</u> Second, major, potentially treatable or preventable sources of erosion and sediment yield are identified through field inventories and prioritized for treatment during field mapping. In high priority watersheds, efforts are made to delineate which roads pose high risk of accelerated or chronic sediment production and delivery, or high long term maintenance costs, and which might be excellent candidates for decommissioning (proper “hydrologic closure,” not just barricading or blocking to traffic). The preliminary transportation plan is revised and

finalized following this field inventory phase.

3) Prescription development: Once sites are identified and prioritized, general prescriptions for erosion control and erosion prevention are developed for each major source of treatable erosion that, if left untreated, would likely result in sediment delivery to streams. Sediment which is contributed to small streams can be as important as that which is delivered directly to major fish-bearing watercourses, since all sediment which enters upland streams will eventually be transported downstream to channels with fish habitat. Generalized prescriptions which should be identified during the field inventory include types of heavy equipment needed, equipment hours, labor intensive treatments required, estimated costs for each work site and expected sediment savings.

4) Treatment recommendations: In the final step of the assessment, a report and plan is developed which outlines recommendations and pinpoints areas within each watershed which would benefit most from cost-effective erosion control and erosion prevention work. In addition, recommendations are made on how on-going land use practices in the watershed might be further modified to reduce the threat of future erosion and sediment yield from on-going land management activities.

We believe requiring proposed work to meet pre-established cost-effectiveness criteria is critical to developing a defensible and objective watershed protection and restoration program. ***The cost-effectiveness of treating a work site is defined as the average amount of money spent to prevent one cubic yard of sediment from entering or being delivered to the stream system*** (Weaver and Sonnevil, 1984). By using this evaluation methodology a variety of different techniques and proposed projects can be compared against each other using the same criteria: reducing accelerated erosion and keeping eroded sediment out of the watershed's streams.

If a watershed sediment assessment is done well, the logical next step will be for skilled equipment operators, laborers and erosion control specialists to immediately implement those projects deemed most cost-effective and most beneficial to long term watershed health and the protection of fisheries resources. Implemented projects can consist of erosion control and erosion prevention work, as well as changes in land use practices (another form of proactive erosion prevention). Pacific Lumber Company generally implements those moderate and high priority sites with a predicted cost-effectiveness of $8/yd$^3$ or less.

Effective watershed stabilization must incorporate both erosion control and erosion prevention work, in concert with protective land use practices. ***Erosion control*** practices for steep forested lands impacted by logging and road building have been thoroughly tested and evaluated and are applicable for most steepland areas (Sonnevil and Weaver, 1981; Weaver and Madej, 1981; Weaver and others, 1981a; Weaver and Sonnevil, 1984; Weaver and others, 1987a; Harr and Nichols, 1993). Projects which provide for ***erosion prevention*** are by far the most cost-effective means of protecting fish habitat and entail the recognition and treatment of potential sediment sources before they become contributors to sediment yield. Finally, simple ***changes in common land use practices*** (such as road and landing construction, road maintenance techniques and road abandonment practices) can often go a long way to preventing unnecessary, accelerated erosion in the future. Many of these practices, as related to forest road systems, are outlined in the appendix “Guidelines for Forest Roads and Landings.”

**Sequence of Assessment Work Tasks and Data Collection Procedures**

The upland watershed sediment source assessment involves several discrete steps or stages.

These steps are a necessary precursor to on-the-ground watershed protection and restoration work which is to be undertaken in the future. They ensure that the most critical, cost-effective erosion prevention and erosion control projects in the watershed are undertaken first.

***Phase 1: Air photo analysis.*** The first step is to assemble and analyze historic aerial photographs, maps, digital mapping data, GIS information and relevant literature available for the watershed. This data is used to construct accurate road maps and to create a general land use and erosion history of the assessment area or sub-watershed, including road locations, road construction history, landslide locations and mass movement history, "road-related" erosion (stream crossing washouts, gullies and landslides, where visible), expected locations of all stream crossings and the location (and timing) of streamside landslides. Stream flow records for this or nearby watersheds are also reviewed to determine information on the magnitude and frequency of historic floods.

An enlarged version of the 7_ minute USGS quadrangle(s), taken from digital map data, is used as the base for identification and location of roads, watersheds and property boundaries in the assessment area. Enlarged versions of the 7_ minute USGS quadrangles can be used to plot road locations, mapped sites and treatment locations. Pacific Lumber Company has sufficient GIS capabilities to produce accurate base maps. Every road that is identified from the aerial photo analysis is then scheduled for field assessment to identify both past and future sediment sources.

Aerial photographs used for field mapping are typically 1:12,000 scale (1 inch equals 1,000 feet), color or black-and-white 9"x9" vertical photos flown as recently as is possible. This is a good scale to employ, as smaller scale photos (e.g., 1:20,000) often do not provide sufficient clarity or detail. Recent photos are often available in true color. The latest photos available for P-L lands are only several years old and new images will be taken in June, 1997. Historic black and white aerial photographs taken in earlier years, beginning in the 1940's, provide a time sequence of images used to isolate periods of harvesting, road building, road abandonment and erosion (especially landsliding) in the watershed.

***Phase 2: Field assessment (inventory).*** Phase two of the watershed sediment source assessment involves field inventories and site analyses. Several levels of field inventory and assessment are carried out. Detailed inventories of all maintained and abandoned road systems are used to identify and determine past and future contributions of sediment to the stream system, and potential treatment sites. The most critical areas and road systems identified during the air photo analysis are inventoried and evaluated in the greatest detail.

For the detailed field assessment, acetate overlays are attached to each 9" x 9" aerial photograph and used to record site location information as it is collected in the field. Information recorded on these overlays includes road location, site number and location (road mileage), type or classification of site, erosional features (stream-side landslides, debris torrents, potential debris slides, gullies and gullied stream channels, washed out stream crossings, etc.), stream channels, stream crossings, landings and all culvert locations. GPS (global positioning) technology is also be used to identify the location of sites for GIS (computer mapping) applications.

A computer database (data form) is then developed and more detailed information is collected for each site of potential sediment yield identified in the field. Depending on the classification of a site (stream crossing, debris slide, gully, road and cutbank erosion, streamside slides, etc.), different portions of the database form are filled in with the relevant information. Basic information is collected for every site.

Identified sites are first classified according to their potential for sediment delivery to stream channels. Very small sites are often not worth inventorying separately, unless they become cumulatively significant (such as road ditches). Past inventories (e.g., Weaver and others, 1981a) have shown that it is typically the larger sites that account for most of the accelerated (land use related) sediment yield from a watershed. Therefore, it is important to identify a lower threshold of sediment yield below which a site is not identified in the field inventory. In most watersheds, this minimum site size may range from 10 $yds^3$ to 50 $yds^3$, depending on the watershed. In large watershed inventories, it is often sufficient to identify those sites where there is a potential to yield at least 25 $yds^3$ or 50 $yds^3$ of sediment to a stream channel (excluding the more diffuse sediment sources such as road surfaces, ditches and cutbanks).

During sub-watershed inventories, special attention is paid to all major stream crossings, all stream crossings with a high diversion potential (DP) and stream crossings with a high failure potential (FP)(e.g.., undersized culverts). Based on past inventory work, each of these categories of stream crossings are assumed to have a high potential for delivering sediment to stream channels, particularly if they are located on roads that are abandoned or no longer receive frequent maintenance. Erosion and failure of stream crossings on abandoned and unmaintained roads, in particular, is likely to eventually occur when culverts plug during large storms. Once erosion has been initiated, sediment lost from these locations will be delivered directly into low order stream channels and, eventually, to the larger fish-bearing streams.

Visibly unstable fillslopes, unstable log landings and unstable hillslopes crossed by either abandoned or maintained logging roads are also described, especially if they threatened to deliver sediment to a downslope stream channel. To be visibly unstable, the identified site usually exhibits tension cracks, vertical scarps, excessive sidecast on steep slopes, springs, leaning trees, or other geomorphic evidence suggesting past or pending slope failure.

The erosion potential, the potential for sediment delivery and the potential for rare, but extreme amounts of erosion are estimated for each major problem site or potential problem site in the watershed. The past and future expected volume of sediment to be eroded, and the volume to be delivered to streams, is also be estimated for each site. The data tells not only how much has been eroded and delivered from existing sites, it also provides estimates on how much will be eroded and delivered in the future, if no erosion control or erosion prevention work is performed. In some locations, future sediment loss could exceed field predictions. At the same time, some inventoried features which show signs of pending or potential failure may never move or deliver sediment to stream channels.

Finally, in addition to erosional features along roads, selected portions of tributary streams within each sub-watershed assessment area are inspected for signs of bank instability, past stream side landsliding or future bank failures. The volume of both past and future erosion and landsliding is estimated and logged on a data form, as well as any obvious associations with past or on-going land management activities, so that initial estimates of the volumetric importance of each erosion process (a sediment source assessment) can be developed. In addition, some of these stream side sites may also be amenable to treatment and stabilization.

***Phase 3: Prescribing treatment.*** During the field inventory of existing and potential erosion sources, a more detailed analysis of each significant site is performed. This step includes an analysis of the most effective and cost-effective erosion prevention and/or erosion control work that could be applied to each of the sites recommended for treatment, including all sites classified as having a high, moderate or low priority for treatment. ***Recommended treatments are generally prescribed only for sites with a potential for future erosion and sediment yield because they are***

***the only ones capable of delivering sediment to downstream fish-bearing stream channels.***

The analysis of each recommended treatment site includes generalized heavy equipment and labor-intensive prescriptions, as well as procedures, cost estimates and equipment times needed for effective treatment. The sites selected for eventual treatment are the ones that are expected to generate the most cost-effective reduction in sediment delivery to the drainage network and the mainstem stream channel. Sites which may experience erosion or slope failure, but which are not expected to deliver sediment to a stream channel, are not recommended for treatment to protect fisheries resources. General treatments are cataloged in the computer database during field examination of each site. The specifics of the recommended treatments, as well as costs and logistics (e.g., equipment types, excavation volumes, equipment hours, etc.) are all outlined in this step.

**Assessing Treatment Priorities Within Each Inventoried Sub-watershed**

As described above, basic treatment priorities and prescriptions are formulated concurrent with the identification, description and mapping of past and potential sources of road-related erosion and sediment yield. Treatment priorities are evaluated on the basis of several factors and conditions associated with each potential erosion site.

1) the expected volume of sediment to be delivered to streams,

2) the potential for future erosion (high, moderate, low),

3) the "urgency" of treating the site (treatment immediacy),

4) the ease and cost of accessing the site for treatments, and

5) recommended treatments, logistics and costs.

The likelihood of erosion (erosion potential) and the volume of sediment expected to enter stream channels from future erosion (sediment delivery) at each site play significant roles in determining its treatment priority. The larger the potential future contribution of sediment to streams, the more important it becomes to closely evaluate its potential for cost-effective treatment. The ***erosion potential*** of a site is a professional evaluation of the likelihood that future erosion will occur. Erosion potential should be evaluated for each site, and expressed as “High,” “Moderate” or “Low.” Erosion potential is an estimate of the potential for additional erosion, based on local site conditions and field observations. Thus, it is employed as a subjective probability estimate, and not an estimate of how much erosion is likely to occur.

***Treatment immediacy*** (treatment priority) is a professional evaluation of how important it is to quickly perform erosion control or erosion prevention work. It is also defined as “High,” “Moderate” or “Low” and represents the severity or urgency of the threat to downstream areas. An evaluation of treatment immediacy considers erosion potential, future erosion and delivery volumes, the value or sensitivity of downstream resources being protected, and treatability, as well as, in some cases, whether or not there is a potential for an extremely large erosion event occurring at the site (larger than field evidence might at first suggest). If mass movement, culvert failure or sediment delivery is imminent, even in an average winter, then treatment may need to be performed as soon as possible and treatment immediacy might be judged "High." ***Treatment immediacy is a summary, professional assessment of a site's need for immediate treatment.*** Generally, sites that are likely to erode or fail in a normal winter, and that are

expected to deliver significant quantities of sediment to a stream channel, should be rated as having a high treatment immediacy or priority.

One other factor influencing a site's treatment priority is the difficulty (cost and environmental impact) of reaching the site with the necessary equipment to effectively treat the potential erosion. Many sites found on abandoned or unmaintained roads require brushing and tree removal to provide access to the site(s). Other roads require minor or major rebuilding of washed out stream crossings and/or existing landslides in order to reach potential work sites farther out the alignment. Road reconstruction adds to the overall cost of erosion control work and reduces project cost-effectiveness. Potential work sites with lower cost-effectiveness, in turn, may be of relatively lower priority. However, just because a road is abandoned and/or overgrown with vegetation is not sufficient reason to discount its assessment and potential treatment. Treatments on heavily overgrown, abandoned roads may still be both beneficial and cost-effective.

**Evaluating Treatment Cost-Effectiveness**

Treatment priorities is developed from the above factors, as well as from the estimated cost-effectiveness of the proposed erosion control or erosion prevention treatment. Cost-effectiveness is determined by dividing the cost ($) of accessing and treating a site, by the volume of sediment prevented from being ***delivered*** to local stream channels. For example, if it would cost $2000 to access and treat an eroding stream crossing that would have delivered 500 yds$^3$ (had it been left to erode), the predicted cost-effectiveness would be $4/yd$^3$ ($2000/500 yds$^3$).

To be considered for priority treatment a site should typically exhibit: 1) potential for significant (>25-50 yds$^3$) sediment delivery to a stream channel (with the potential for transport to a fish-bearing stream), 2) a high or moderate treatment immediacy and 3) a predicted cost-effectiveness value of no more than about $8/yd$^3$. Other criteria may be important in selected watersheds, including domestic water supplies, listed aquatic species or other valuable downstream resources. Treatment cost-effectiveness analysis is often applied to a group of sites (rather than on a single site-by-site basis) so that only the most cost-effective groups of projects are undertaken. During road decommissioning, groups of sites are usually considered together since there will be only one opportunity to treat potential sediment sources along the road.

Cost-effectiveness can be used as a tool to prioritize potential treatment sites throughout a sub-watershed (Weaver and others, 1981b; Weaver and Sonnevil, 1984). It assures that the greatest benefit is received for the limited funding that is typically available for protection and restoration projects. Sites, or groups of sites, that have a predicted marginal cost-effectiveness value (>$8/yd$^3$), or are judged to have a lower erosion potential or treatment immediacy, or low sediment delivery rates, are less likely to be treated as a part of the primary watershed protection and "erosion-proofing" program. However, these sites are usually addressed during future road reconstruction (when access is reopened into areas for future management activities), or when heavy equipment is performing routine maintenance or restoration work on nearby, higher priority sites.

**Reducing Watershed Sediment Risks through Preventive Treatments and Protective Measures**

A variety of treatments are applied to prevent erosion and sediment yield to stream channels from roads and other eroding areas within each sub-watershed. These include erosion-proofing along roads and landings, total or partial road decommissioning, road upgrading and specific treatments along eroding stream banks, gullies and other bare soil areas. Sites which are expected to erode

<u>and</u> deliver sediment to streams in the future are the <u>only</u> locations where opportunity exists for meaningful erosion control and erosion prevention work in a watershed. At these locations, a variety of specific treatments are employed to control and prevent future erosion and sediment delivery to stream channels.

***Risk reduction through road decommissioning and road upgrading***

A critical first-step in the overall risk-reduction process is the development of a watershed transportation analysis and plan. All roads in each planning watershed are considered for either decommissioning or upgrading, depending upon the risk of their impacting the aquatic ecosystem. Not all roads are high risk roads and those that pose a low risk of impacting aquatic habitat in the watershed may not need immediate attention. It is therefore important to rank and prioritize roads in each sub-watershed based on their potential to impact downstream resources, as well as their importance to the overall transportation system and management needs in the watershed.

***Decommissioning:*** Roads which are of low relative priority for decommissioning include those which follow low gradient ridges, roads traversing large benches or low gradient upland slopes, and roads with few or no stream crossings. Roads that are no longer needed for land or resource management may or may not fall into a high risk classification for removal because of where they are located in the watershed. For example, many dead-end spur roads which lead to cable yarding landings high on the hillslope fit into this category of low priority roads for decommissioning. Even though these routes might be relatively easy and inexpensive to permanently close, they are not high priority candidates for immediate decommissioning since their removal will do little to protect the downstream aquatic ecosystem.

These types of low impact seasonal and temporary roads may be identified for closure, but their removal from the transportation system may do little to protect or remove real threats to the aquatic ecosystem. It is important to also identify more substantial, permanent roads for removal if they pose significant threat to the aquatic system. Estimating the future sediment yield and treatment cost-effectiveness of projects along all roads (as described above) will help identify which roads in the watershed are truly the best targets for decommissioning.

Based on potential threats to the aquatic ecosystem, a variety of roads qualify as "best-candidates" for decommissioning. These often include roads built in riparian areas, roads with a high potential risk of sediment production (such as those built on steep inner gorge slopes and those built across unstable or highly erodible soils), roads built in tributary canyons where stream crossings and steep slopes are common, roads which have high maintenance costs and requirements, and abandoned roads. General techniques for decommissioning (described below) are well documented and tested, and costs and procedures for each type of activity have been established (Sonnevil and Weaver, 1981; Weaver and others, 1987a; Weaver and Hagans, 1990; Harr and Nichols, 1993; NPS, 1992).

***Upgrading:*** In most managed watersheds, some roads are typically needed to provide for long term resource management, for administrative access, for fire control and for other purposes. Roads which are best suited for retention need to be identified in the transportation planning process for each sub-watershed. To be protective of fish habitat and the aquatic ecosystem in the watershed, this planning first considers the erosional consequences of road retention, and then the expressed needs for management activities.

Retained roads are those that are expressly needed for management or as a component of the overall transportation network. They are typically, but not exclusively, located on stable terrain, where the risk of fluvial erosion, stream crossing failure, storm damage and mass soil movement (landsliding) is lowest. Each retained road is then upgraded and redesigned as necessary, to make them largely self-maintaining or requiring low levels of maintenance.

A variety of "upgrading" techniques are available to make these stable, well located roads as "storm-proof" as is possible. The goal of road upgrading is to strictly minimize the contributions of fine sediment from roads and ditches to stream channels, as well as to minimize the risk of serious erosion and sediment yield when large magnitude, infrequent storms and floods occur.

Fine sediment contributions from roads, cut banks and ditches in refuge watersheds are minimized by utilizing seasonal closures for hauling and travel, road surfacing, converting ditched insloped roads to outsloped alignments (especially at and near the approaches to stream crossings), adding rolling dips to drain and disperse road surface runoff, and adding rolling dips or ditch relief culverts immediately adjacent stream crossings (to reduce extension of the drainage network and eliminate ditch contributions to sediment yield).

Specific techniques employed to storm-proof forest roads include increasing culvert size to accommodate the 50-year flood discharge (or greater), replacing large culverts with bridges, replacing culverted fills with hardened fords in areas where debris torrenting is common or can be expected, eliminating the potential for stream diversion at all high risk stream crossings, stabilizing or removing unstable fills and sidecast, and realigning road segments to avoid instabilities and recognized headwater swales where landsliding and debris torrenting is likely to occur.

***Types of prescribed heavy equipment erosion prevention treatments***

Generic specifications for a variety of preventive watershed treatments have been developed for decommissioning and erosion-proofing (upgrading) roads and landings throughout the Pacific Northwest. Recommended treatments may range from no treatment or simple waterbarring, to full road decommissioning, including the excavation of unstable sidecast materials, road fills, and all stream crossing fills. Each of the treatments prescribed for roads or hillslopes have been well tested, documented and evaluated in similar erosion control and erosion prevention projects on steep forested lands, and have been shown to be effective in significantly reducing sediment yield from managed forest lands (Harr and Nichols, 1993; Sonnevil and Weaver, 1981; Weaver and others, 1981a; Weaver and others, 1987a,b; Weaver and Sonnevil, 1984).

***Road upgrading*** involves a variety of treatments used to make a road more resilient to large storms and flood flows. The most important of these include stream crossing upgrading (especially culvert up sizing and elimination of stream diversion potential), removal of unstable sidecast and fill materials from steep slopes, and the application of drainage techniques to improve dispersion of road surface runoff. Standard road upgrading techniques are well documented and understood (for example, see Pacific Watershed Associates, 1994c).

Road upgrading costs may not differ significantly from those required for road decommissioning. Costs are highly dependent on the frequency and nature of the potential erosion problems along the alignment, the number and size of stream crossings whose drainage structures must be upgraded, the number of bridge installations required, road surface treatments and surfacing requirements, as well as the size (volume) of unstable fills that must be excavated and end hauled to stable spoil disposal locations.

General heavy equipment treatments for ***road decommissioning*** are newer and less well published, but the basic techniques have been tested, described and evaluated (Harr and Nichols, 1993; Weaver and others, 1987a; Weaver and Sonnevil, 1984). Decommissioning essentially involves "reverse road construction," except that full topographic obliteration of the road bed is not normally required to accomplish sediment prevention goals. In order to protect the aquatic ecosystem, our goal is to "hydrologically" decommission the road; that is, to minimize the adverse effect of the road on natural hillslope and watershed hydrology. From least intensive to most intensive, decommissioning and upgrading tasks for roads will include at least some of the following tasks[1]:

1. ***Road ripping or decompaction***, in which the surface of the road or landing is "decompacted" or disaggregated using mechanical rippers. This action reduces surface runoff and often dramatically improves revegetation.

2. ***Rolling dip installation/construction (critical dip),*** involves dipping the roadbed at stream crossings on maintained roads where the potential for stream diversion is high, thereby assuring that when culverts plug, stream flow will be directed over the road prism and back into the natural stream channel, rather than down the road bed. Rolling dips are also installed along roads to drain the road surface and disperse excess surface runoff.

3. ***Waterbars and cross-road drains*** are installed at 50, 75, or 100-foot intervals, or as necessary at springs and seeps, to disperse road surface runoff, especially on roads that are to be permanently or temporarily decommissioned. Cross-road drains are large ditches or trenches excavated across a road or landing surface to provide drainage and to prevent the collection of concentrated runoff on the former road bed. Waterbars are also installed on season roads that are closed during the wet season.

4. ***Installing or cleaning culverts,*** includes adding new or larger culverts where they are needed, or cleaning the inlets or outlets of partially plugged culverts on maintained roads. Correct installation procedures are briefly described in the accompanying text "Guidelines for Forest Roads and Landings."

5. ***In-place stream crossing excavation (IPRX)*** is a decommissioning treatment that is employed at locations where roads or landings were built across stream channels. The fill (including the culvert) is completely excavated and the original stream bed and side slopes are exhumed. Excavated spoil is stored at nearby stable locations where it will not erode, sometimes being pushed several hundred feet from the crossing by tractor(s). A stream crossing excavation typically involves more than simply removing the culvert, as the underlying and adjacent fill material must also be removed and stabilized.

6. ***Exported stream crossing excavation (ERX)*** is a decommissioning treatment where stream crossing fill material is excavated and spoil is hauled off-site for storage. Spoil is moved farther up- or down-road from the crossing, due to the limited amount of stable storage locations at the excavation site. This treatment frequently requires dump trucks to endhaul spoil material to the off-site location.

7. ***In-place outsloping (IPOS)*** ("pulling the sidecast") calls for excavation of unstable or

[1]Many of these and other erosion prevention and erosion control techniques are describe in the accompanying text "Guidelines for Forest Roads and Landings."

8. potentially unstable sidecast material along the outside edge of a road prism or landing, and replacement of the spoil on the roadbed against the corresponding, adjacent cutbank, or within several hundred feet of the site. Placement of the spoil material against the cutbank usually blocks access to the road and is used in road decommissioning. In road upgrading, the excavated material can be used to build up the road bed and convert an insloped, ditched road to an outsloped road.

9. ***Exported outsloping (EOS)*** is comparable to in-place outsloping, except spoil material is moved off-site to a permanent, stable storage location. Where the road prism is very narrow, where there are springs along the road cutbank or where continued use of the road is anticipated, spoil material is typically not placed against the cutbank and material is end hauled to a spoil disposal site. This treatment frequently requires dump trucks to endhaul spoil material. This t treatment removes all or part of the roadbed.

Only in relatively few instances does road decommissioning have to include full recontouring of the original road bed. Typically, potential problem areas along a road are isolated to a few locations (perhaps 10% to 20% of the road network to be decommissioned) where stream crossings need to be excavated, unstable landing and road sidecast needs to be removed before it fails, or roads cross potentially unstable terrain and the entire prism needs to be removed. Most of the remaining road surface simply needs permanently improved surface drainage, using decompaction, road drains and/or partial outsloping.

Successfully decommissioning most roads will cost a fraction of complete or total topographic road obliteration, and can be significantly less expensive than road upgrading. Costs are highly dependent on the frequency and nature of the potential erosion problems along the alignment. Table 1 lists a number of treatments and their typical applications.

**Table 1.**
**Sample techniques and applications for decommissioning forest roads**

| **Treatment** | **Typical use or application** |
|---|---|
| Ripping or decompaction | improve infiltration; decrease runoff; assist revegetation |
| Construction of rolling dips and cross-road drains | drain springs; drain insloped roads; drain landings |
| Partial outsloping<br>(local spoil site; fill against the cutbank) | remove minor unstable fills; disperse cutbank seeps and runoff |
| Complete outsloping<br>(local spoil site; fill against the cutbank) | used for removing unstable fill material where nearby cutbank is dry and stable |
| Exported outsloping<br>(fill pushed away and stored down-road) | used for removing unstable road fills where cut banks have springs and cannot be buried |
| Landing excavations<br>(with local spoil storage) | used to remove unstable material around landing perimeter |
| Stream crossing excavations<br>(with local spoil storage) | complete removal of stream crossing fills<br>(not just culvert removal) |
| Truck endhauling (dump truck) | hauling excavated spoil to stable, permanent storage location where it will not discharge to a stream |

***Labor intensive erosion control and revegetation treatments***

Hand labor is typically used for both revegetation and erosion control work at sites disturbed by heavy equipment, at sites where drainage structures need repair or upgrading, and where hand labor is needed to assist in excavation work. Hand labor is also needed on sections of road that are recommended for upgrading. Labor work at drainage structures include such preventive tasks as adding culvert downspouts and trash racks, adding extensions to culverts, cleaning culvert inlets, cleaning debris out of the channel above a culvert inlet, and assisting in culvert installation or replacement.

Labor intensive erosion control treatments are often needed on sites where heavy equipment has been used to perform road decommissioning. Their use is primarily confined to those measures required to stabilize and revegetate soils exposed by heavy equipment operations. Only the most effective and cost-effective labor techniques should be prescribed. These include mulching, seeding and planting. In general, heavy equipment will perform most of the significant erosion prevention and erosion control work in drainage basins and along road networks.

***Control of chronic sediment yield from roads and roadside ditches***

Road cutbanks and road ditches are thought to deliver relatively significant volumes of fine sediment to some watersheds in the Pacific Northwest (Reid, 1981) and they have been found to significantly affect watershed hydrology (Wemple, 1994). Relatively simple treatments will also be performed to upgrade P.L. road drainage systems to significantly reduce or largely eliminate these watershed effects. Fine sediment can usually be prevented from entering culverted stream crossings by installing ditch relief culverts or rolling dips just up-road from stream crossings, or by outsloping roads in the immediate vicinity of stream crossings (Pacific Watershed Associates, 1994a). Such treatments also reduce the hydrologic impacts of roads (e.g., increased peak flows and timing of peak flows) on watershed function.

***Reducing watershed risks through other land management measures***

Physical treatment of the erosion control and erosion prevention work sites is a useful and necessary step in watershed stabilization. It is one of two complementary methods for "erosion-proofing" and "protecting" a watershed from future impacts. The second and perhaps the most cost-effective tool for minimizing future erosion and sediment delivery to fish-bearing streams is the use of preventive land use practices and protection measures which limit watershed disturbances.

Throughout field mapping of active and abandoned roads, timber harvest sites, rock pits and grazing areas throughout each sub-watershed, observations are kept on the effect of past and current land use practices on erosion and sediment delivery to stream channels. Certain combinations of land use practices and site variables (soils, slope gradient, bedrock geology, slope position, etc) are may be documented to contribute to, or influence, the magnitude or location of watershed erosion. Based on field observations and watershed assessment and inventory data, current and future land use practices can then be modified in that watershed to help provide “passive” protection to downstream aquatic resources, especially from impacts which occur during infrequent floods.

Practical protection measures related to road networks and timber harvesting are developed to address issues such as improved road location and design standards, operations (including timber harvesting) on steep inner gorge slopes or other suspect geomorphic locations, road construction and drainage practices, stream crossings, road maintenance practices, gullying and stream bank erosion and road decommissioning. For grazed lands, grazing allocations, riparian planting and fencing, localized exclosures, seasonal restrictions and other “passive” measures can be employed to lessen the potential for sediment-related impacts to stream channels.

As with other forms of watershed conservation practices, erosion prevention is usually far more cost-effective than trying to control erosion once it has begun. Most of the recommendations for land use activities that stem from a watershed assessment and inventory focus on prevention.

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## ATTACHMENT

### Explanation/Instruction for Road Inventory Data Form

The following field inventory dataforms are examples of the types of data, related to storm-proofing watersheds, currently being collected on Pacific Lumber lands. The data collection process is iterative. As we gain new knowledge about ecosystem processes, the specific questions on the data form will change to reflect our increased understanding.

The Field Inventory Data Form (Figure 2) was developed to assist in the assessment of past and potential future erosion problems, including their nature, cause, magnitude and solution. It is used to identify and classify erosion problems, to prioritize potential work sites, and to prescribe specific watershed treatments aimed at protecting stream channels and fish habitat.

Use of this work sheet is intended to provide a standardized and comparable analysis of observed features throughout a watershed. Using this form, field personnel can measure, describe and interpret landforms and erosional problems in a consistent and uniform manner. In addition, data is most useful if it is collected in a computerized database format that will allow for inventory information to be rapidly searched, analyzed and used to prepare a work plan for implementation.

Based on field observations and interpretive remarks provided on this form, and developed through additional site inspections, land managers will be provided with a prioritized listing of the most critical, on-going and potential sediment sources within each basin.

The following text is provided to help explain the intent and meaning of many of the questions, and to suggest the format of possible answers, contained on the Inventory Data Form (Figure 2). Not all questions are applicable for each site identified in the field. Only those questions which are applicable for a site should be answered, and only the type of answer allowed (e.g., Yes or No,... or a number) should be given. Comments can be made in the comment sections. Figure 3 has been included to illustrate the types of data collected along selected stream channels during watershed assessment efforts. The questions are largely self explanatory, therefore no instructions for use of the landslide form have been provided at this time.

1. <u>Site Number:</u> The identification name or number given this specific site. Each site should have a unique ID number for future reference which is shown on an aerial photo mylar overlay. The number is also used to identify each site in database searches.

2. <u>Mileage</u>: For each site that could be reached by a vehicle, a "mileage" is logged on the photo overlay map and on the computerized data sheet. Mileages are typically given from the start of the road for each site that could be reached by vehicle. If the road was not driveable, the word "WALK" is used instead of a mileage. The length of walking-roads is then determined from digitizing maps or aerial photographs.

3. <u>Photo</u>: The flight line and frame of the air photos used for mapping. Original field mapping information is contained on an acetate overlay for each of the aerial photos covering the assessment area.

4. <u>Sketch?:</u> Have you made a sketch of the site (on the back of the data form)?

5. <u>Road Name</u>: The name of the road which the site is located on, or nearest to. Many roads have posted names, such as the #500 Road. Other roads will be un-named and you will have to develop a logical numbering system.

6. Maintained (Y,N): Is the road currently being maintained? Is there evidence of maintenance activities having been performed recently? (Y,N)

7. Abandoned (Y,N): Answered "Yes," if the road is abandoned or blocked, and unmaintained. The road may still be driveable, but it is classified as abandoned if there is no obvious maintenance to the culverts, the ditches are not cleaned, and vegetation is overgrowing the roadbed. Spur roads are also considered abandoned if they are completely and permanently blocked at their beginning. Gated roads are not necessarily considered abandoned, but they may be. If the road is not "abandoned," then it is considered "maintained."

8. Driveable (Y,N): Could you drive on the road, or are there obstructions, washouts or vegetation that make it impossible?

9. Inspector(s): Use the names or initials of the inventory crew.

10. Date (mapped): The date the field mapping for this site was carried out.

11. Watershed: The name of the watershed (from the map or from the landowner).

12. Year Built: This is the first year the road showed up on aerial photographs. This is not likely the year it was constructed. The construction history for roads in the assessment area is obtained from maps and aerial photographs.

13. Treat (Y,N): The answer to this question represents our final recommendation as to whether on not this site should be treated. It is answered: "Y" if the site should be treated, "Y?": if the site should be treated if equipment is at or near the site doing other work and "N" if this site is not recommended for treatment.

14. Sediment Yield (Y,N): Will this site yield sediment to a stream channel if it is left untreated? If this question is answered “no” then you probably don’t need to fill out a data sheet (it’s not a site).

15. Upgrade?: Are the recommended measures aimed at upgrading and “storm-proofing” this road?

16. Decommission?: Has this road been “decommissioned?” or is it being recommended for decommissioning?

17. Problem Type (circle): Circle the appropriate type(s) of problems at each locality. (Note: gullies are new channels that have a cross sectional area over 1 $ft^2$ (1'x1'). Gullies are caused by concentrated surface runoff (often below culvert outfalls, on skid trails or on large bare areas such as landslide scars) or by stream diversions. Anything smaller is considered a rill and lumped with surface erosion processes. Streambank erosion is often natural and unavoidable but can be accelerated by the build-up of bed deposits in the channel, deflected stream flow caused by landslides or debris in the channel, or by increases in discharge.)

18. Road Fill Failure (Y,N): This just involves the outside edge of the road prism, where loose material was pushed over the side during road construction. These failures can show up many years after construction.

19. Landing Fill Failure (Y,N): This just involves the outside edge of the log landing, where loose material was pushed over the side during landing construction. These failures can show up many years after construction.

20. Deep Seated Slide (Y,N): These features usually cover fairly large areas with multiple scarp systems running through natural slopes and/or across roads and skid trails. Characterized by emerging groundwater, leaning trees, active and inactive scarp systems, and episodic, seasonal movement from several feet to several hundred feet annually. Some may not move annually. Most deep seated landslides are difficult and expensive to control. They usually involve much more than just the road fill.

21. Cutbank slide (Y,N): This is a landslide that is confined to the cutbank on the inside of the road. Usually, these landslides just dump material on the road bed and none of it gets into the stream channels. Some of the bigger slides can go right over the road and down slope into a channel. Cutbank slides are usually just maintenance problems (not sediment yield problems).

22. Already failed (Y,N): Landslides which have already failed are generally inactive features that have partially or largely revegetated and show no significant signs of pending erosion or sediment delivery. Gullies will often have armor lag deposits in the channel bed. Landslides may be inactive even though vegetation is still sparse and it still looks bad.

23. Potential failure (Y,N): Features which are assigned this category are thought to be potentially ready and waiting to fail. They may be currently inactive (showing no signs of movement in the last several years), but the scarps and other indicators suggest that during an especially large storm the instability could become active and fail or move downslope. It may also be part of slide that already failed, but there is still a chunk ready to go.

24. Dist. to stream (ft): How far is it from this landslide site from the nearest stream (where sediment would be delivered), in feet?

25. Slope (%): What is the slope of the hillside below the site, in percent? This is the slope of the natural ground below the base of the fill slope, not the slope of the road fill looking from the outside edge of the road. You will likely have to go down to the foot of the fillslope to take a good measurement with your clinometer.

26. Stream Crossing Type: Stream crossings are locations where ephemeral, intermittent or perennial streams cross a road. The crossing may be a culverted crossing, a bridge, a Humboldt log crossing, or a fill crossing that never had any drainage structure installed. Mark "Y" or circle the applicable answer.

27. Diameter (CMP)(in inches): This is the culvert diameter, in inches. Typical choices include 12, 18, 24, 30, 36, 42, 48, 52, 60, 72. Measure each culvert with a measuring tape because it is easy to be fooled and guess incorrectly.

28. Pipe condition (O,C,R,P): This question requires three answers - the Inlet, the Outlet and the Bottom of the culvert pipe. O = OK; C = Crushed; R = Rusted (severe, to the point of having holes in the bottom); P = Plugged (anything over about 20% blocked should be marked "plugged").

29. Headwall height (inches): Headwall height measurements are only made on stream crossings with culverts. Measure the vertical height from the bottom of the culvert inlet to the lowest point in the stream crossing fill where the water would begin to flow out of the crossing and down the ditch, or over the fill on onto the road. Some headwall height measurements will be made to the low point on the inboard edge of the road and others will be made to the ditch. You have to figure out where the low point is and where water would flow if the culvert were to plug.

30. CMP slope (%): What is the average slope of the culvert? This measurement can be taken by

looking up the culvert from the outlet, or down the culvert from the inlet. Use a clinometer. If the culvert is straight, you can place you clipboard in the culvert inlet, put your clinometer on you clipboard and read out the slope gradient.

31. Stream Class (1, 2, 3): These are the stream classed used by Fish and Game and the Department of Forestry. Basically, Class I are fish bearing at some time of the year, Class 3 move sediment but don't provide any habitat to bugs or amphibians. Class 2 are the rest (have bugs and/or amphibian habitat at some time of the year.

32. Ditch/rd length (ft): The length of road and ditch which contributes surface runoff (and fine road sediment) to the stream crossing.

33. % washed out (%): if the crossing is eroding, how much of it has gone? Is it 10% washed out or is it 50% washed out. If it is completely washed out you put "100." Culverted stream crossings can wash out by having stream flow over the fill, by having extreme culvert outlet erosion or by having a Humboldt log crossing develop sink-holes and subsurface gully erosion.

34. ? (Y,N): Does the crossing have a high diversion potential? (Y or N) That is, if the culvert plugged, would flood waters spill over the road and back into the stream channel (No D.P.) or would the water flow down the road or ditch (High D.P.). All stream crossings (where roads cross over stream channels) have either no DP or a high DP. There are no other choices. If the crossing has No D.P., overflow might cause the fill to be washed out, but the streamflow would not be diverted out of its channel. If the crossing has a High D.P., the fill crossing at the point of diversion would not wash out but a gully would form down the road, in the ditch and/or where the water left the road and crossed the slope.

35. Diverted (Y,N): Is the stream currently diverted down the road?

36. Plug potential (H,M,L): This is the estimated potential for this culvert (or Humboldt log crossing) to plug with sediment or woody debris (High, Moderate or Low). It has a plug and high failure potential if the capacity is too small, or if the culvert could be easily plugged. This is an **estimate** of how likely the culvert is to plug in the next big storm. The amount of mobile organic debris and sediment being transported in the channel and whether or not an adequate trash rack is in place (some crossings work fine without a trash rack because little debris moves in the channel during storms) are considered.

37. Channel gradient (%): The slope of the natural channel upstream from the stream crossing, in percent. Do not measure channel gradient in the flat reach influenced by the stream crossing and culvert inlet.

38. Channel dimensions (W, D): The dimensions of the expected flood flow (peak) natural channel width and depth, measured in feet, upstream from the crossing in a section of stream un-affected by the stream crossing.

39. Sed Transport (H,M,L): This is the relative capability of the stream to transport sediment (and thereby move sediment and debris down to the culvert inlet) (answered: High, Moderate or Low). This is a subjective and relative observation that needs to be "calibrated" in the field.

40. Erosion Potential (H,M,L): The estimated potential for additional erosion is a judgement call, based on observations already taken, as to the potential for additional, significant erosion at this site. This is a probability estimate, not an estimate of how much erosion is likely to occur. The answer is either **H**igh, **M**oderate or **L**ow.

41. Past Erosion (yds): The volume of past erosion ($yds^3$) at the site is recorded. The volume is

typically derived from field measurements. Width, depth and length measurements can be recorded here also. If the feature is complex, several different measurements may be given to account for the entire feature.

42. Delivery (%): This is an estimate of the percent of the past eroded material that was actually delivered to the stream channel system.

43. Future Erosion (yds$^{3}$): This is the estimated volume of future erosion. It is determined by taking quantitative planimetric measurements in the field and calculating the size and volume of potential erosion that would be generated. This question calls for an estimate, but the estimate is based on field observations and measurements. For existing gullies, potential and existing landslides and potential stream crossing washouts, it is possible to estimate the volume of future erosion that is likely to occur.

Volumes are easiest to estimate for potential stream crossing washouts, because the fills placed in the channels when roads are built are fairly regular in shape and you can assume most of the fill would eventually be lost if the culvert plugged and the crossing washed out by fluvial erosion.

Next, over steepened landings generate limited volumes of sediment when they fail by debris sliding, and these quantities can be estimated fairly easily.

Existing, enlarging gullies lengthen, widen and deepen until they become stable and the final dimensions (hence volumes of future erosion) may be estimated. Indeed, many existing gullies that were formed during major storm events and still look raw may already be largely stable. Most sediment to be eroded from these features may well be limited to gradual bank retreat and collapse.

Debris slides (landslides) generated from steep headwater swale areas (usually where they are crossed by roads) are limited in size at the point of origination. However, debris slides generated at these sites often grow much larger as they move down the steep channels and scour debris from the channel bed. This makes their final volumes sometimes much larger than that estimated at the initiation site itself. Use your best judgement and base your volume predictions for such features on occurrences that have been documented or observed in your area. If your estimate includes additions of material scoured from channels and downslope areas, via these debris torrent mechanisms, make sure you differentiate the two sources on the check sheet.

The future volumetric yield of large translational landslides can be difficult to estimate largely because they move episodically, they move at unpredictable rates and they occasionally become self-stabilized after moving for a period of time. Such slides are typically bounded by scarps or other natural features that place an upper bound on the amount of material that is **likely (or possible)** to move downslope and into a stream channel. However, this is an upper limit and not a reasonable estimate of the expected future volume. Instead, an estimate is made of what portion of the mass is likely to move downslope before the feature eventually stabilizes. Potential volumetric contributions from debris slides and other "fast" mass movements can be predicted much more easily than yields from episodically active translational landslides.

44. Future Delivery (%): Will future eroded sediment enter a stream channel? If any of the future eroded sediment will enter a stream channel and could eventually be washed to downstream areas, then there will be delivery. If all the eroded sediment will be stored on the slope and never move into the stream system then there will be no delivery. This is an estimate of how much sediment (expresses as a % of the volume of expected erosion) that is likely to be

delivered to the stream channel.

45. (WxLxD): Measurements of the potential erosion feature, expressed as average Width X Length x Depth. If the feature is complex, several different measurements may be given to account for the entire feature. These measurements describe the planimetric assumption used by field personnel to determine future erosion volumes.

46. Comment on problem(s): The summary comments for each site generally describe the nature of the erosion problem and important site characteristics. The summary comments section is here to help the reader quickly gain a feel for the site without having to read all the detailed questions that follow.

47. Treatment Immediacy (H,M,L): The subjective answer to this question lets you decide if the work needs to get done right now! or later. Is the feature falling apart and going to change dramatically this coming winter? Does erosion at this site seriously threaten important downslope or downstream resources (eg spawning or rearing areas)? Answer "High", "Moderate" or "Low" (no big rush, but erosional problems or potential erosion source should be corrected in the future). This is question that field personnel summarized how critical it is to perform erosion control work at this site. This answer is based on the severity of the potential erosion, its volume, its predicted activity level and the sensitivity of the resources at risk.

48. Complexity (H,M,L): A subjective estimate of the difficulty of performing the recommended treatment. For example, a simple stream crossing excavation or the excavation of a small unstable fill along the outboard edge of the road would usually be categorized as LOW complexity. On the other hand, a 1,000 $yd^3$ excavation of a Humboldt log crossing which will require construction of a lower access road and dump truck endhauling may be classified as a HIGH complexity site. It is best to explain your thoughts in the comment section at the bottom of the data sheet.

49. Mulch area ($ft^2$): This is the expected area that will be bared by heavy equipment operations. This area may need mulching and seeding to control erosion after operations are complete. Many sites located away from stream channels will not need these treatments. Only if bare soil could erode and be delivered to a stream channel is there a need to mulch and seed.

50. Possible Treatments, "Y" is placed next to recommended treatments. “Excavate soil” is reserved for excavations where the soil will be permanently removed from the site (thus, replacing or installing a culvert is not marked “excavate soil” because all the dirt is placed back in the hole - if some dirt is permanently removed from the work site, then mark “excavate soil).

51. Total volume excavated ($yds^3$): This is the total volume of material which must be excavated from the unstable fillslopes or stream crossings at this site. This volume is used to help predict costs and equipment times needed to perform the excavation work. In addition, it is used to help determine whether endhauling will be necessary to dispose of spoil from the site. Questions related to the excavation of fill crossings on abandoned roads: This is actually the estimated volume of material that will have to be excavated from the stream crossing site to prevent future erosion and sediment delivery. In many cases, because the stream banks must be sloped back to a stable gradient, slightly more sediment will have to be excavated from the crossing than would eventually fail or be washed away by fluvial erosion. The computational field procedure for estimating excavation volumes are not described here.

52. Volume put back in ($yds^3$): This is the volume of material that is to be put back in the “hole,” as in a new culvert installation or a culvert replacement.

53. Volume removed ($yds^3$): This is the volume of excavated material that will not be put back into

the excavation “hole.” A good example would be the excavation of unstable sidecast material - zero would be “put back in” and all of it would be “removed.” Express these numbers in cubic yards.

54. Volume stockpiled ($yds^3$): How much of the excavated spoil can you pile locally (without using dump trucks).

55. Volume endhauled ($yds^3$): From measurements in the field, the available storage volume is calculated and compared to the total excavated volume to determine the need for endhauling equipment. If local storage is insufficient, additional storage sites will have to be found in nearby areas along the road. Endhauling requires dump trucks.

56. Exc. Production rate ($yds^3$/hr): State the production rate (excavation rate) your have used for this site to calculate the needed equipment hours. Use the comment section at the bottom of the page to itemize how many hours of each piece of equipment are assigned for each task and sub-task. See the “cheat-sheet” for some general guidance in estimating equipment production rates for various tasks).

57. Equipment hours: If a piece of equipment is to perform several different tasks or subtasks, then list the individual times that go together to add up to total equipment time for each piece of equipment.

    Excavator (hrs) - estimated hours of excavator time needed for direct excavation at the work site. This estimate does not include time for travelling or other miscellaneous tasks.

    Dozer (crawler tractor) (hrs) - estimated hours of tractor time needed for direct excavation at the work site. This estimate does not include time for travelling or other miscellaneous tasks.

    Dump trucks (hrs) - estimated hours of dump truck time needed for endhauling excess spoil to stable storage locations.

    Grader (hrs) - estimated hours of road grader time needed for direct excavation and road work at the work site. This estimate does not include time for travelling or other miscellaneous tasks.

    Loader (hrs) - estimated hours of loader time needed for direct excavation at the work site. This estimate does not include time for travelling or other miscellaneous tasks.

    Backhoe (hrs) - estimated hours of backhoe time needed for direct excavation at the work site. This estimate does not include time for travelling or other miscellaneous tasks.

    Labor (hrs) - estimated hours of laborers needed to perform such tasks as culvert installation, culvert cleaning, etc.

    Other - This category is reserved for any other tasks or equipment not listed above.

58. Comment on treatment: Included in this comment section are estimated equipment hours needed for backhoes, dump trucks, etc. In addition, details for equipment or labor treatments and logistics may be outlined in this comment. You should strive to fill this comment with useful information.